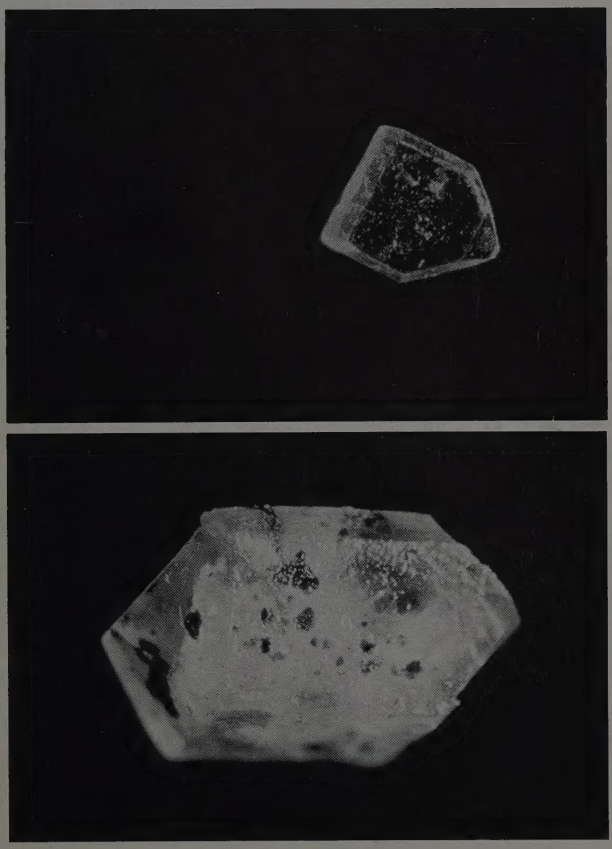
HAWAIIAN PLANTERS' RECORD



Vol. LVI 1960 No. 2

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On the Cover: Commercial Sugar Crystals

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NON-SUCROSE CONSTITUENTS IN RAW SUGAR CRYSTAL

PART I. RELATIONSHIP BETWEEN NON-SUCROSE CONSTITUENTS AND CRYSTAL SIZE

K. Onna and C. C. Tu*

INTRODUCTION

The internal structure of the sucrose crystal is characterized by irregular layer growth (1) as shown in Figure 1. If the degree of supersaturation at the front of the growing layer is lowered by a high rate of crystallization or a decreased medium motion, the mother liquor at a crystal face may be overgrown by a continuous crystal layer (3). This may be observed in Figure 2, which shows the inclusion of colorless mother liquor in a commercially refined sucrose crystal, and in Figure 3, which shows the inclusion of colored suspensoids. When unfavorable conditions persist, the regions of mother liquor inclusion may broaden into channels and large areas where inclusion can take place (Figure 4).

The presence of non-sucrose constituents on the surfaces of a crystal may alter the relative growth rates of the different faces. When this occurs, the crystal form will no longer be isometric due to the appearance of secondary faces (Figure 5). As growth proceeds, the inclusion of mother liquor and the development of internal stresses may cause fractures, as shown in Figure 6. Non-uniformity of

Figure 1. Layer growth on raw sucrose crystal.

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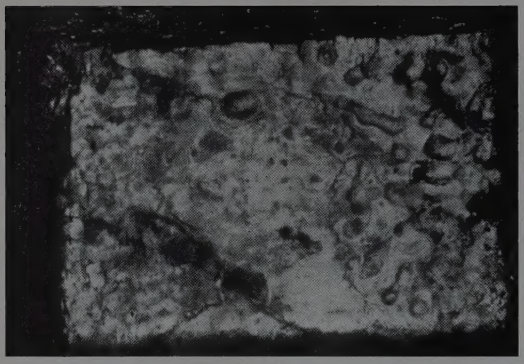

Figure 2. Globules of colorless mother liquor trapped within a a commercially refined sucrose crystal.

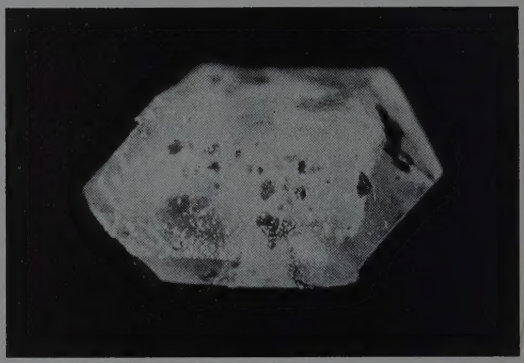

Figure 3. Inclusion of colored suspensoids. Starch coated with tannin extract was allowed to be overgrown by continuous crystal layers.

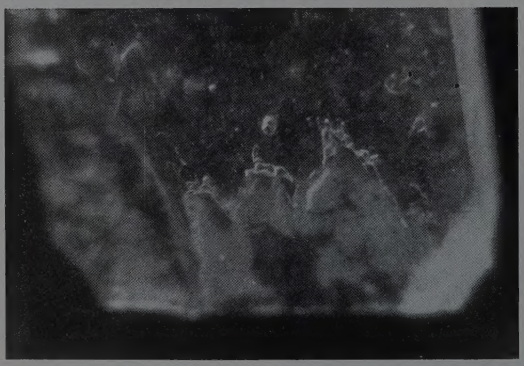

Figure 4. Channels formed by regions of mother liquor inclusions broadening into a large area.

crystals under this condition will be pronounced. The degree of non-uniform growth and imperfection of crystals can act as factors leading to increased inclusion of non-sucrose constituents.

It has been established (2, 3, 4) that the inclusion of mother liquor increases as crystal size becomes larger. This is due to the greater probability that non-uniform conditions will exist on the surfaces of larger crystals.

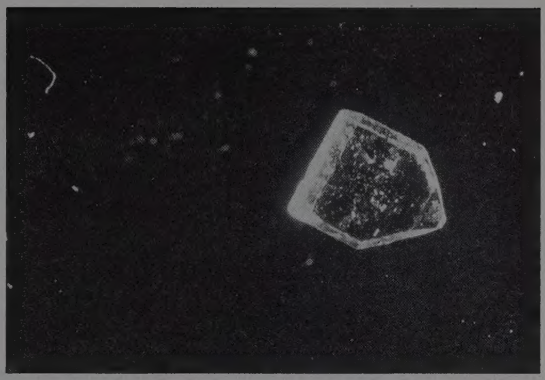

Figure 5. Non-isometric sucrose form resulting from changes in growth rates of the primary crystal faces.

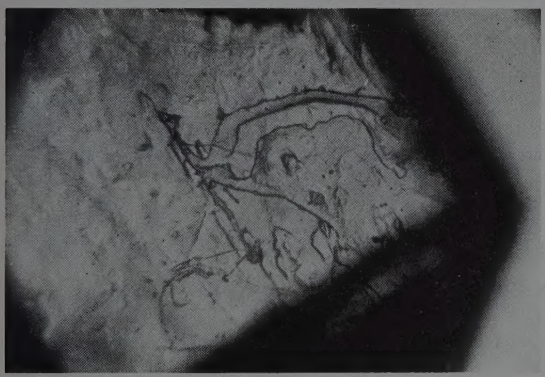

Figure 6. The appearance of cracks on a raw sucrose crystal resulting from the development of stresses due to mother liquor inclusion.

It should follow, therefore, that larger sucrose crystals grown under the same conditions should contain more non-sucrose constituents than smaller crystals. This has been confirmed by a study of crystals grown from the same strike of commercial sugar.

PROCEDURE

Separation and Washing of Crystals

Non-composite samples of raw sugar crystals from commercial strikes were used in this investigation. Ten-pound portions of the sugar and four liters of methanol were added to a 10-liter jar, and the contents were gently shaken every five minutes for half an hour. The methanol was removed by filtration through a 100-mesh screen. The operation was repeated once with methanol and twice with iso-propanol. The sugar was dried by oven heating at 80° to 90° C. for three and one-half hours. One-pound portions of the dried sugar were separated into screen fractions by shaking for 15 minutes on a Ro-tap screening machine (U.S. Tyler Standard Screen Scale). The crystals from each screen fraction were washed four times by mingling with 67° brix granulated sugar solution, rinsed four times with methanol, and stored in sealed bottles after being air-dried.

Crystal Color

Forty grams of a crystal fraction and 1.00 gram of filter aid were added to 100 milliliters of distilled water. After the sugar had dissolved, the pH was adjusted to 7.0 by the dropwise addition of 0.05 N sodium hydroxide and 0.05 N sulfuric acid. The mixture was filtered through Whatman No. 1 paper and the first 10 milliliters of filtrate were discarded. The attenuation index of the subsequent filtrate was determined at 420 millimicrons on a Bausch and Lomb Spectronic 20 Colorimeter.

Transmittancy through the visible region was measured on a Beckman DK-2 Spectrophotometer.

Specific Conductance

Ten grams of sugar were dissolved in water and the solution was made up to 200 milliliters. Specific conductance was measured on a Leeds and Northrup 4961 sugar ash bridge using a No. 4924 conductivity cell.

Aqueous Methanol Insoluble Substances

Two hundred and twenty-five grams of sugar were refluxed in one liter of 85 per cent (v/v) methanol. After one to two hours, the insoluble substances were recovered by centrifuging the hot solution. The precipitates were then successively washed in acetone and ether, and dried under reduced pressure.

RESULTS

The results obtained with a sample of Paauhau sugar are given in Table 1.

TABLE 1. ANALYSIS OF PAAUHAU SUGAR BY CRYSTAL SIZE

Crystal Size (mesh)			%	Attenuation Index (420 mμ) × 10	Spec. Cond. meg. mho	85% Methanol Insol. %
Retained	14		0.9	13.0	55	0.42
Through 14	"	16	5.2	11.0	43	0.28
" 16	"	20	9.5	9.7	40	0.21
" 20	"	28	37.9	9.1	36	0.12
" 28	"	35	31.7	7.8	32	0.18
" 35	"	48	10.9	7.8	33	0.18
" 48	"		3.9	8.4	44	0.56

These show that a decrease in crystal color, conductivity, and 85 per cent methanol-insoluble substances accompanied a decrease in crystal size. Specific conductivity data for individual strike sugar samples from Waialua, Wailuku and Pepeekeo also showed similar patterns (Table 2). Transmittancy curves in the visible region for different grain size fractions of these sugars are given in Figure 7. These show also that the larger crystal fractions are more highly colored.

TABLE 2. SPECIFIC CONDUCTANCE OF SUGARS BY CRYSTAL SIZE

Crystal Size (mesh)			meg. mho		
			Waialua	Wailuku	Pepeekeo
Retained	16		50	84	35
Through 16	"	20	43	58	32
" 20	"	28	39	50	24
" 28	"	35	39	44	22

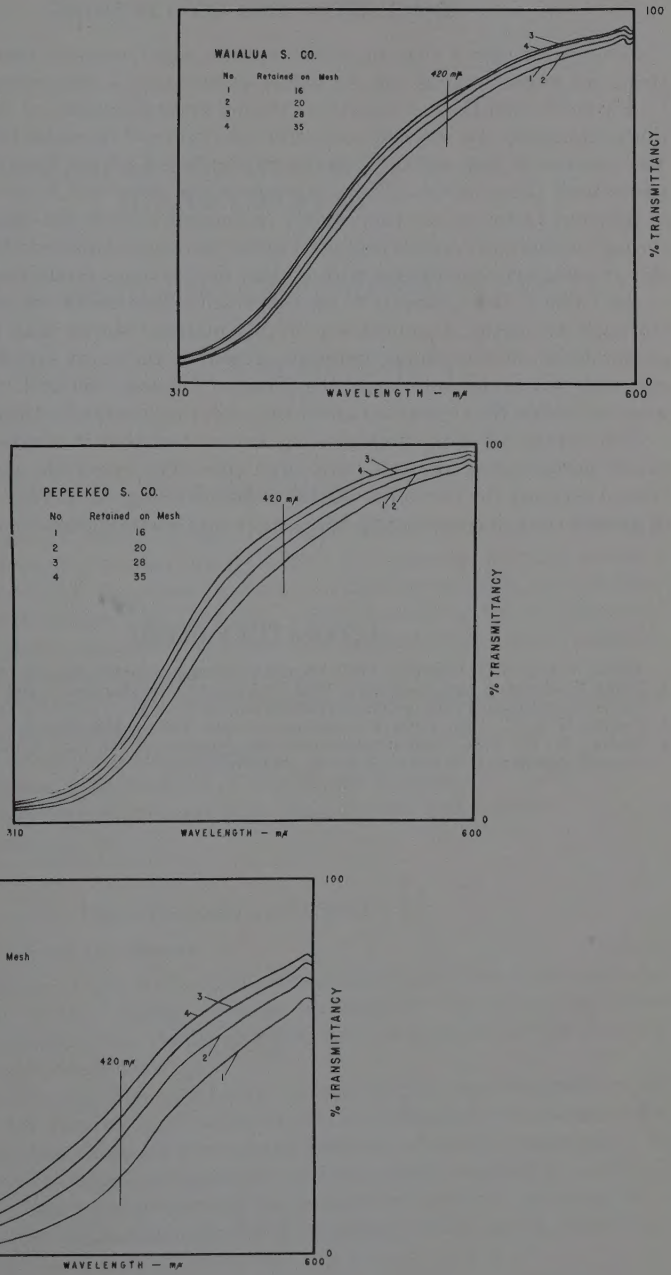

Figure 7. Transmittancy curves according to grain size for sugar from an individual strike at three plantations (Waialua, Pepeekeo and Wailuku).

DISCUSSION AND CONCLUSIONS

This work shows that in non-composite sugar crystals from a commercial strike the larger crystals contain higher percentages of non-sucrose constituents.

Physical conditions encountered during crystallization, as well as composition of the syrup and molasses, determine the rate and character of crystal growth. The amount of non-sucrose constituents included within the crystal, therefore, varies with these factors. Thus, crystals of the same size from different strikes or different factories can vary widely in amount of included material. It is only through a study of crystals produced under the same conditions that the relationship of included constituents with crystal size becomes established.

In Table 1, there appears to be a reversal in the case of the very fine fraction (through 48 mesh). Examination of this material shows that it contained an accumulation of extraneous materials present in the sugar sample. Among these materials were relatively large quantities of bagasse, soil and iron scale. These were not within the crystal but affect the analytical results for the fine fraction.

The results serve to emphasize the known fact that it is easier to grow more nearly perfect small crystals than large ones. The larger the crystals the more critical becomes the control to obtain uniformity of growth. With non-uniformity of growth come inclusions and hence more non-sucrose constituents.

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NON-SUCROSE CONSTITUENTS IN RAW SUGAR CRYSTAL

PART II. CLASSIFICATION OF COLOR SUBSTANCES

C. C. Tu and R. H. Okamoto*

INTRODUCTION

A principal quality factor of the raw sugar crystal is its color. Although several groups of organic compounds are known to be present in small amounts within the crystal (3,5), the characterization of these compounds has not been reported. An investigation was, therefore, undertaken using the techniques of paper chromatography and paper electrophoresis to clarify the chemical composition by isolating the substances contributing to color.

The following classes of non-sucrose constituents related to color substances were separated and identified:

1. Naturally occurring plant pigments.
2. Alkaline degradation products of glucose and fructose.
3. Thermal degradation products of sucrose, glucose, and fructose.
4. Melanoidins.

PROCEDURES AND RESULTS

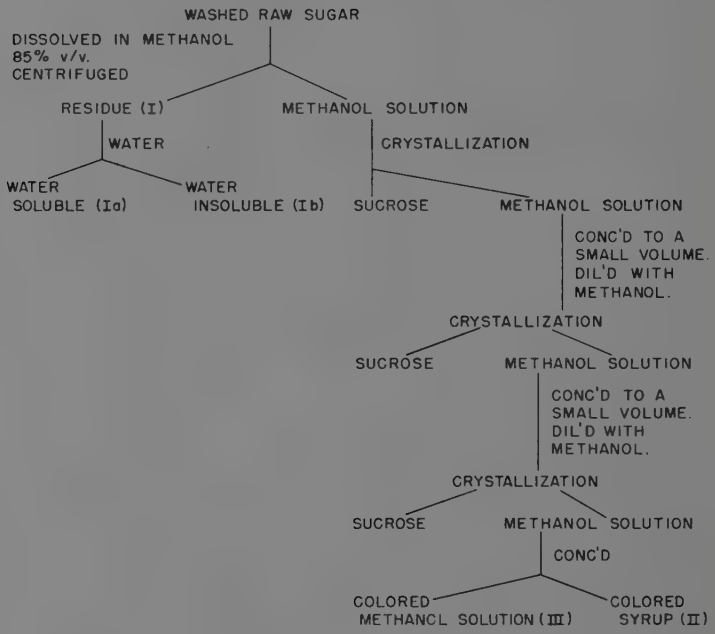
Separation of Non-Sucrose Constituents

The initial phase of this study involved the classification of constituents by their solubility in various media, as shown in Table 1. The subsequent phase involved the separation and identification of the constituents in the classified groups by the methods indicated.

During the initial separation, a highly colored fraction was obtained for the syrup (II) and for the methanol solution (III). Preliminary chromatographic analyses of these two fractions showed the presence of similar materials. The methanol solution contained water-soluble material which was highly soluble in the methanol. Chromatograms revealed the presence of naturally occurring flavonoid pigments, the degradation products of sugars, amino acids, nonnitrogenous organic acids and inorganic material.

* Senior Sugar Technologist and Laboratory Assistant, respectively, Experiment Station, HSPA.

TABLE I. ISOLATION OF COLOR SUBSTANCES



Paper electrophoresis of the syrup (II) showed that two negatively charged bands, one brown and one yellow, moved toward the anode. The yellow band was further resolved into five bands which were fluorescent under ultra-violet light. A positively charged brown band migrated toward the cathode. As electrophoresis proceeded, a gradual disappearance of the brown band occurred simultaneously with the appearance of two substances, one ninhydrin-reactive and the other heat-sensitive. The electrophoregrams are shown in Figures 1 and 2.

Two groups of amino acids, one basic and one acidic, were also separated by electrophoresis. The amino acids present in major quantities were found to be aspartic and glutamic acids.

Characterization of the Plant Pigments

The methanol solution (III) in Table 1 was further concentrated to a small volume. The concentrated solution was transferred onto a cellulose column, 30 × 330 mm. The column was eluted with the solvent mixture ethyl acetate : acetic acid : water (6:3:2 v/v). The effluent was fractionated by an automatic fractional collector. The volume of each fraction was five ml. After the 96th fraction was collected, the effluent was colorless. The 33rd, 46th, 60th, and 80th fractions were spot-checked by paper chromatography, using the solvent mixtures ethel acetate : acetic acid : water (6:3:2 v/v), n-butanol : acetic acid : water (4:1:5 v/v), and m-cresol : acetic acid : water (50:2:48 v/v). The chromatograms were sprayed with Godin's reagent, ferric chloride (two per cent in methanol),

Figure 1. Electrophoregrams of color substances. Fluorescent zones under ultraviolet light at (a) zero-hour, (b) one-hour, (c) two-hour, and (d) four-hour electrophoresis.

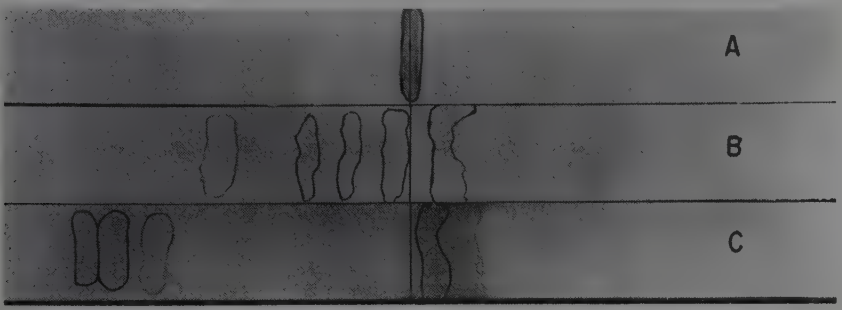


Figure 2. Electrophoregrams of color substances. Fluorescent zones under ultraviolet light at (a) zero-hour and (b) three-hour electrophoresis, and (c) color zones developed with ninhydrin solution after three-hour electrophoresis.

TABLE 2. R_f-VALUES RELATED TO THE PLANT PIGMENTS PRESENT IN THE CRYSTAL

Ethyl acet.:HOAc:H_2O (6:3:2)	n-BuOH:HOAc:H_2O (4:1:5)	m-cresol:HOAc:H_2O (50:2:48)	Possible plant pigments
	0.03	0.00	
	0.10	0.01	anthocyanins
	0.37	0.22	
		0.42	
	0.56		
0.46	0.80		
	0.72	0.22	
	0.85		
		0.81	catechins
		0.90	

TABLE 3. THERMAL DEGRADATION OF DRIED SUGARS AT 110° C

Sugar	Heating interval hours		Change of color	Possible thermal reactions	Possible thermal degradation products
Fructose	1)	17	light brown	1) degradation	1) anhydrides 2) unsaturated reducing compounds a) from the reversion products b) from the anhydrides and fructose 3) sugar humic substances 4) sugar tar and carbon
	2)	41	brown		
	3)	65	dark brown		
	4)	89	dark brown	2) condensation or polymerization	1) reversion products of fructose 2) polymerization products of unsaturated compounds
	5)	137	dark		
Sucrose	1)	482	brown	1) thermal fission	glucose and fructose
	2)	510	brown	2) degradation	1) anhydrides 2) unsaturated reducing compounds 3) sugar humic substances 4) sugar tar and carbon
	3)	582	brown		
	4)	745	dark brown	3) condensation or polymerization	1) reversion products of glucose and fructose 2) polymerization products from the unsaturated reducing compounds
	5)	1,081	black		
Glucose		1,200	light brown	The rate of thermal degradation of glucose is very slow as compared with that of fructose or sucrose.	

sodium borohydride, and five per cent ammoniacal silver nitrate. It was found that the fractions between the 33rd and 46th contained the naturally occurring flavonoid plant pigments, based upon their R_f-values as compared with those reported (2,1), and that the fractions between the 60th and 80th contained the degradation products of sugars. The R_f-values related to the plant pigments are shown in Table 2.

Alkaline Degradation of Glucose and Fructose

Twenty-five grams of the sugar (glucose or fructose) were mixed with 20 grams of calcium hydroxide in 500 ml. of water. The mixture was maintained for 16 days at room temperature, with occasional shaking. On standing, the solution changed to brown. The excess of calcium hydroxide was removed by filtration and the filtrate was evaporated to 400 ml under reduced pressure. The residual calcium was removed by passing the solution through Amberlite IR-120 cation exchange resin (150 grams). The deionized solution was concentrated to a thin syrup. After the removal of saccharinic acids, the highly colored solution was concentrated to a thick syrup.

Another 12 grams of fructose were mixed with 10 grams of calcium hydroxide in 250 ml of water. The mixture was maintained, with occasional shaking, for 18 days at room temperature. A white mass was first formed, which, on standing, gradually disintegrated, producing a yellowish-brown solution. The mixture was filtered and the filtrate was concentrated to 250 ml. The residual calcium and saccharinic acids were removed as described above. The solution was concentrated to a thick syrup.

The syrups obtained by the alkaline degradation of glucose and fructose were examined by paper chromatography and paper electrophoresis. Chromatograms and electrophoregrams indicated that the degradation products contained several colored organic acids. During the course of electrophoresis in an alkaline medium, two colored bands were separated from each other; the colored band migrating toward the cathode gradually disappeared.

THERMAL DEGRADATION OF SUGARS

Five portions of 20 grams each of glucose, fructose, and sucrose were heated in an oven at 110° C. At intervals, as shown in Table 3, samples were withdrawn, and the change in color at each interval was noted. Examination of the degradation products was made by means of paper chromatography. A suitable solvent was found to be n-butanol : pyridine : water (6:4:3 v/v). Each sample was spotted on Whatman No. 1 paper. The paper strips were irrigated, then sprayed with the following reagents: Godin's reagent, ferric chloride (two per cent in methanol), aniline hydrogen phthalate, p-anisidine phosphate and five per cent ammoniacal silver nitrate solutions. Table 3 lists the possible degradation products based upon the chromatographic results.

Electrophoresis of thermal degradation products of fructose was also done. Electrophoregrams indicated that the thermal degradation products consist of two groups of brown-colored substances migrating toward opposite directions in an electric field. The two colored bands were separated from each other, but neither changed color.

DISCUSSION AND CONCLUSIONS

Plant Pigments

Some of the color substances in the methanol solution (III) in Table 1 were found, by chromatographic methods, to be naturally occurring pigments. Based upon R_f-values, the possible pigments present in raw sugar are shown in Table 2. Anthocyanins were found to be the major plant pigments. The types of pigments present in cane are dependent upon the cane varieties and the environment of cane growth. However, the naturally occurring color in cane juice, except for chlorophyll, is mainly due to the presence of these polyphenolic compounds whose color can be intensified by oxidation or interaction with other compounds.

Alkaline Degradation of Glucose and Fructose

The degradation of glucose and fructose by alkali under nitrogen atmosphere usually leads to the formation of saccharinic acids and lactic acid, as reported by Kenner and Richards (4). In cane processing, lime is added to the juice to neutralize organic acids and to effect clarification. When alkaline degradation of the reducing sugars takes place in the presence of air and at an elevated temperature, a great number of other organic compounds can be produced in addition to a group of hydroxy acids. The brown-colored substances, obtained by alkaline degradation at room temperature in a nitrogen atmosphere, and migrating toward the cathode in an alkaline buffer, gradually disappeared as electrophoresis proceeded, but reappeared when the electrophoregrams were subjected to heat or to prolonged exposure to air. This indicated that the disappearance of the brown color was probably due to isomerization. The brown-colored substance migrating toward the anode remained unchanged. Based upon the colored spots on chromatograms sprayed with Godin's reagent, the brown-colored substances were found to consist of a mixture of organic acids. The isomerization and the reappearance may be due to the presence of alkali-labile groups, probably carbonyl(s) and enediol(s), which are responsible for the coloration. However, some of the brown-colored substances in raw sugar appear to be formed by the alkaline degradation of glucose and fructose. This conclusion is based upon a comparison with alkaline degradation products of known sugars.

Thermal Degradation of Sugars

Fructose is more sensitive to heat and more susceptible to the formation of brown-colored substances than sucrose and glucose. The thermal degradation of fructose is accompanied by the simultaneous condensation or polymerization of its degradation products. These two reactions occur continuously under the influence of heat. The belief that highly colored substances are produced by condensation or polymerization of the degradation products of sugars is based on the chromatographic observation which revealed diminishing quantities of low molecular weight compounds (high R_f-values) as color developed. The continuous thermal degradation of sugars and the condensation or polymerization of the degradation products appear to be largely responsible for the formation of brown-colored substances in processing of raw sugar.

Electrophoretic studies indicated that at least two groups of brown-colored substances migrated toward opposite directions in an alkaline buffer. The color of the two brown bands which separated from each other remained unchanged during electrophoresis.

One product from the thermal degradation of fructose which migrated toward the cathode is similar to hydroxymethylfurfural. Both the product and hydroxymethylfurfural gave the same R_f-values and same color reaction with p-anisidine phosphate. When the chromatograms were sprayed with ferric chloride (two per cent in methanol) and Godin's reagent, a difference was shown between the product and hydroxymethylfurfural; only the latter developed a colored spot on paper with ferric chloride solution. This indicated that the previously described products are unsaturated in nature and are unstable reducing compounds as indicated on chromatograms.

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NON-SUCROSE CONSTITUENTS IN RAW SUGAR CRYSTAL

PART III. COLOR FORMATION FROM REDUCING SUGARS

C. C. Tu, R. H. Okamoto and K. Onna*

INTRODUCTION

Two types of substances were found to be responsible for a large proportion of the color in the raw sugar crystal. This paper covers the preparation and characterization of color substances from the degradation of reducing sugars, and from the reaction between glucose and amino acids which produces melanoidin.

PROCEDURES AND RESULTS

Preparation of Melanoidin (1,2)

Two grams of glucose and five grams of alanine were dissolved in 30 ml. of water and the solution was refluxed for 15 hours. After heating for 20 minutes, a dark-brown solution was formed; precipitation occurred after heating for several hours. Electrophoregrams from an alkaline buffer indicated that the melanoidin contained two colored bands which migrated in opposite directions. The band which migrated toward the cathode was similar to that found in raw sugar crystal. The results obtained by paper chromatography showed that both the precipitate and the solution of melanoidin consisted of several acids and unreacted glucose and glycine.

Color Substances from Reducing Sugars (3,5)

Thirteen grams of sucrose were dissolved in 30 ml. of water and the solution was inverted with five ml. of concentrated hydrochloric acid at 70° C. for five minutes. The pH was adjusted to 11, and the solution was refluxed for 10 hours. Precipitation occurred after heating for several hours. The pH was 4.6 at the end of this time. Electrophoresis of the colored solution and the precipitate was made in the usual manner. On the electrophoregrams, a brown-colored band which had migrated toward the cathode proved to be similar to that found in raw sugar crystal. Chromatograms developed by using n-butanol : pyridine : water (6:4:3) indicated that fructose was almost completely decomposed and that a considerable amount of glucose remained unchanged. Other chromatograms developed by phenol : water (80:20) indicated that both the solution and the precipitate con-

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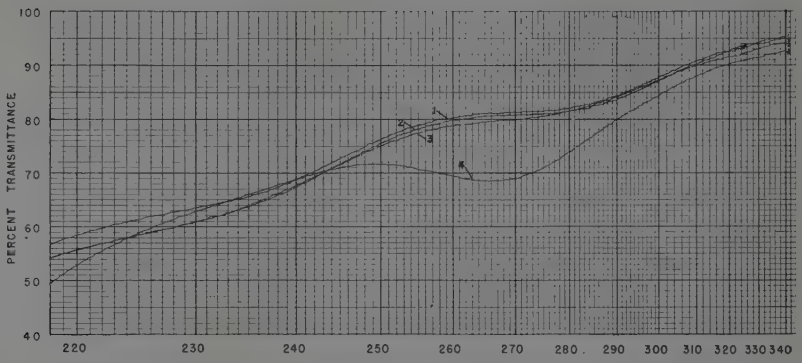

Figure 1. Transmittancy curves of glucose solutions. (1) pH at 4.5, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

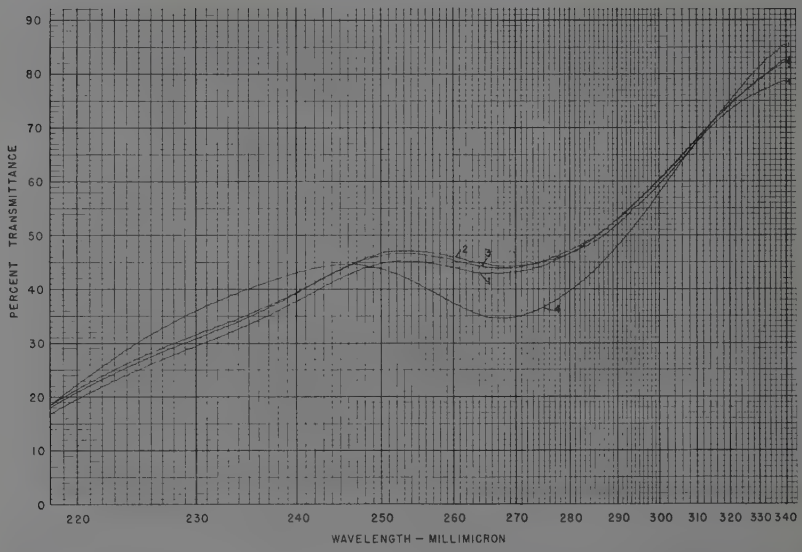

Figure 2. Transmittancy curves of glucose solutions. (1) pH at 6.8, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

tained a group of acids similar to those found in raw sugar crystal. The precipitate was alkali-soluble. The color of the solution was affected by changes in pH; when pH was raised, the brown color was greatly intensified.

Color Substances from Glucose

Two 18 per cent glucose solutions, one at pH 6.5 and the other at pH 9.0, were heated at 80° C. for four and one-half hours. The solution with pH 9.0 developed a very little color, but the other yielded none. The pH of the alkaline

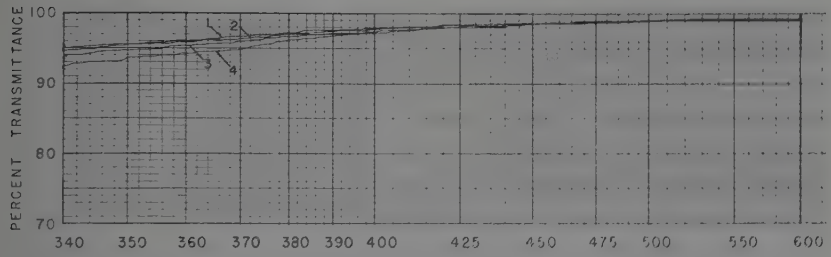

Figure 3. Transmittancy curves of glucose solutions. (1) pH at 4.5, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

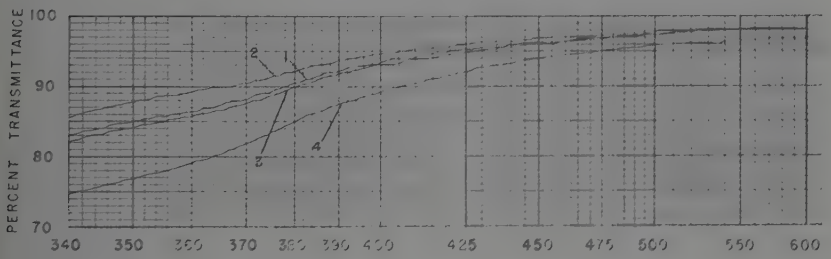

Figure 4. Transmittancy curves of glucose solutions. (1) pH at 6.8, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

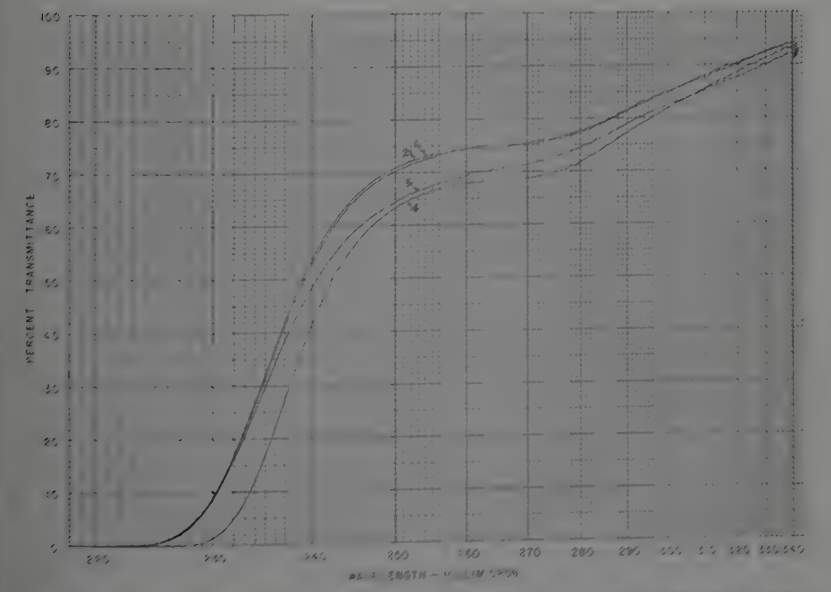

Figure 5. Transmittancy curves of glycine solutions. (1) pH at 4.0, (2) pH at 4.0 adjusted after heating, (3) pH at 6.5, (4) pH at 9.0

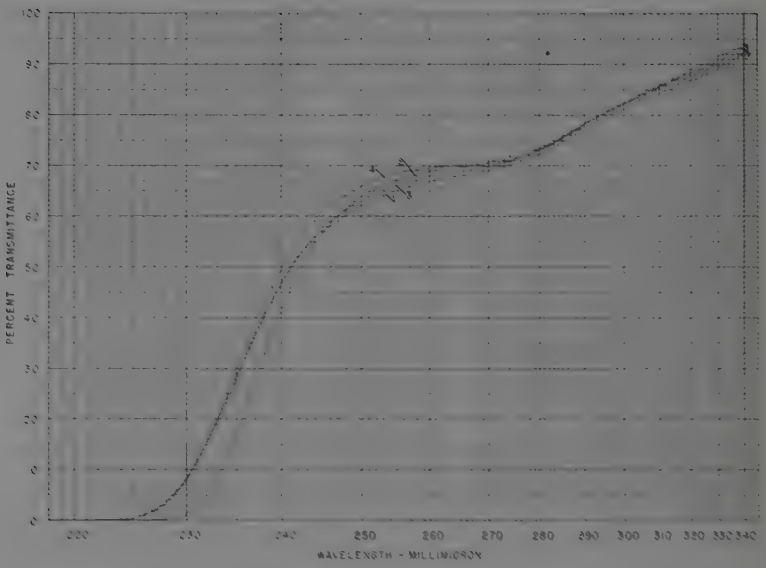

Figure 6. Transmittancy curves of glycine solutions. (1) pH at 6.6, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

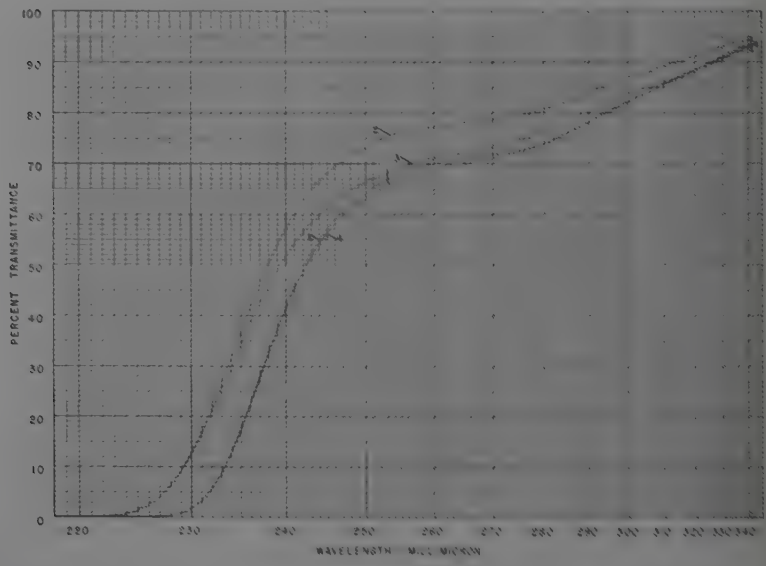

Figure 7. Transmittancy curves of glycine solutions. (1) pH at 8.9, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

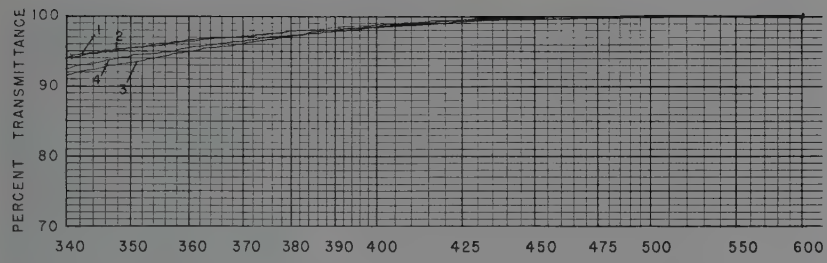

Figure 8. Transmittancy curves of glycine solutions. (1) pH at 4.0, (2) pH at 4.0 adjusted after heating, (3) pH at 6.5, (4) pH at 9.0

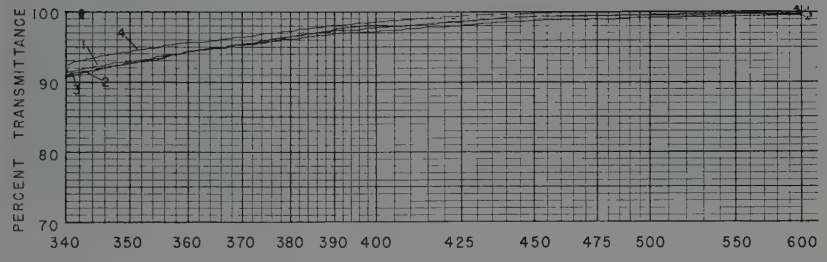

Figure 9. Transmittancy curves of glycine solutions. (1) pH at 6.6, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

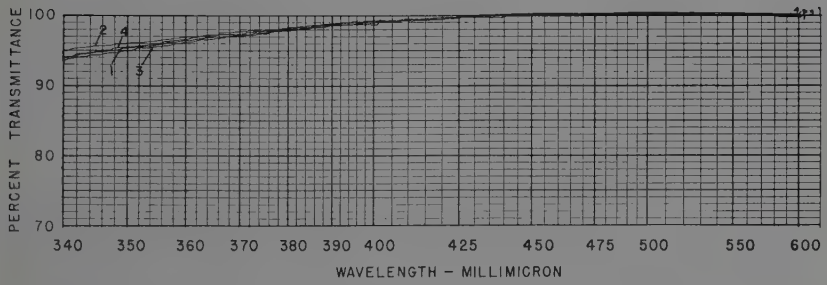

Figure 10. Transmittancy curves of glycine solutions. (1) pH at 8.9, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

solution was 6.8 after heating. The transmittancy curves from different pH values in the ultraviolet and visible regions are shown in Figures 1, 2, 3, and 4.

No Color from Glycine Alone

Two 3.3 per cent glycine solutions, at pH 6.5 and 9.0 respectively, were heated for four and one-half hours at 80° C. Neither solution yielded any color. The transmittancy curves from different pH values in the ultraviolet and visible regions are shown in Figures 5, 6, 7, 8, 9, and 10.

Figure 11. Ratio Recording Spectrophotometer (Beckman DK-2)

Spectrophotometric Measurements

(a) *Melanoidin.* Forty-five grams of glucose and 9.4 grams of glycine were dissolved in 250 ml. of water. Three portions of this solution were separately adjusted to pH 4.0, 6.5 and 9.0. Each solution was heated at 80° C. for four and one-half hours. The solution at pH 4.0 did not develop any color; the solution at pH 6.5 became brown-colored; and the solution at pH 9.0 turned dark brown. No precipitation occurred after each solution had been heated. At pH 9.0, a part of glucose was transformed into fructose, as observed on chromatograms. After this heating period, the pH values of the solutions were reduced from 6.5 and 9.0 to 6.2 and 7.3, respectively. Optical measurements of the colored solution, as described above, at pH 4.0, 6.5, and 9.0, were made on a ratio-recording spectrophotometer (Figure 11). The transmittancy curves obtained at different pH values from the melanoidin solutions are shown in Figures 12, 13, 14, and 15. A small difference in transmittancies at the different pH values is shown in Figures 14 and 15.

(b) *Color substances from reducing sugars.* Optical measurements were made at pH values 4.0, 6.5, and 9.0 of the colored solutions, prepared as described above. The transmittancy curves in the ultra-violet and visible regions are shown in Figures 16 and 17. These curves show that the differences in transmittancy at the different pH values are much greater than those from melanoidin.

(c) *Raw sugar crystal solutions.* Transmittancy curves on solutions of sugars from monthly composites prepared for crystal color measurements at 420 mμ were made at pH values of 4.0, 7.0, and 9.0. These are shown in Figures 18, 19, 20, 21, and 22.

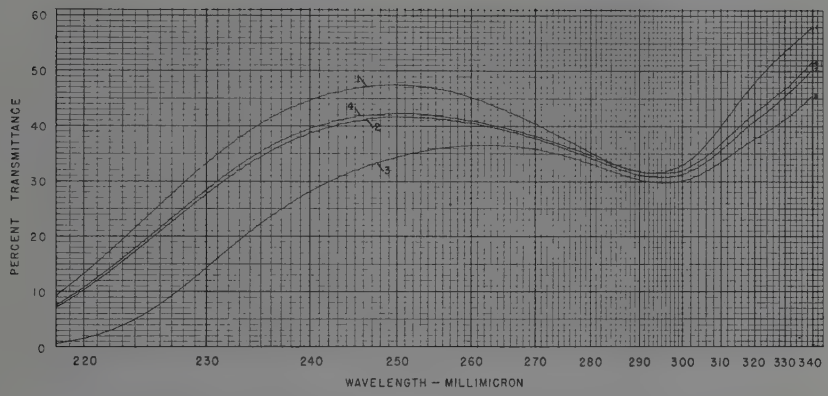

Figure 12. Transmittancy curves of solutions of glucose and glycine (1) pH at 4.0, (2) pH at 6.5, (3) pH at 9.0, (4) pH at 6.2

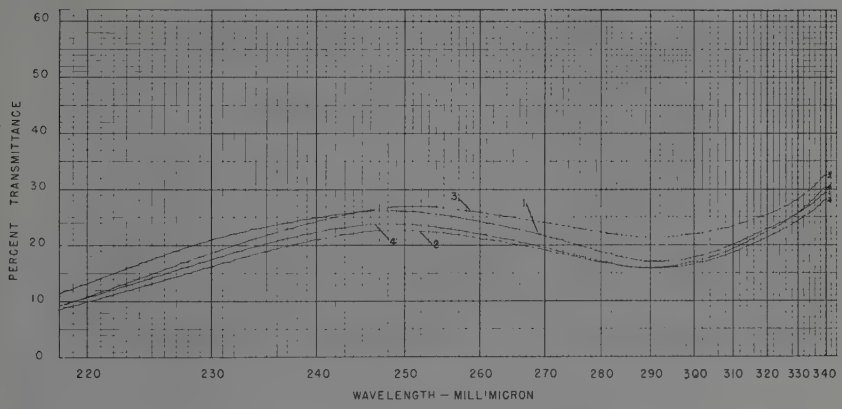

Figure 13. Transmittancy curves of solutions of glucose and glycine. (1) pH at 4.0, (2) pH at 65., (3) pH at 9.0, (4) pH at 7.3

DISCUSSION AND CONCLUSIONS

Reducing sugars and amino acids have often been held largely responsible for the development of color during the manufacture of raw sugar. The possible degradation products have been reported as anhydrides, unsaturated reducing compounds, and polymers of the degraded products. Most of these very reactive substances are also colored.

The color substances obtained from the thermal degradation of reducing sugars constitute a group of organic acids. The color of these degradation products increases with increasing pH. This change in color under the influence of pH is probably due to structural alterations of those color substances produced from the thermal degradation of reducing sugars. One such possible rearrangement

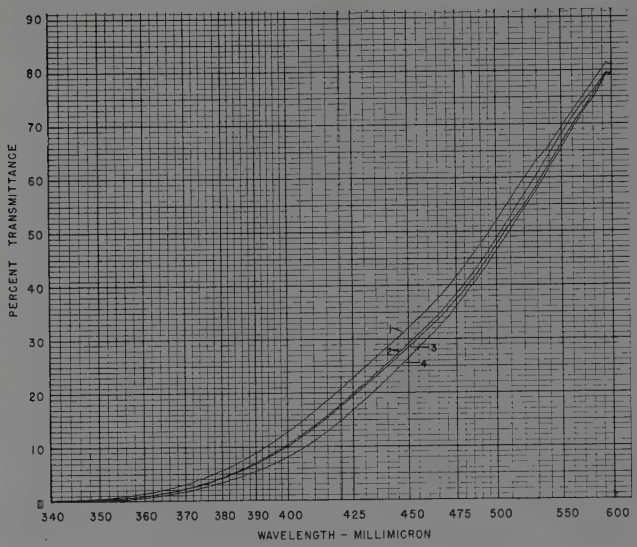

Figure 14. Transmittancy curves of solutions of glucose and glycine. (1) pH at 4.0, (2) pH at 6.2, (3) pH at 6.5, (4) pH at 9.0

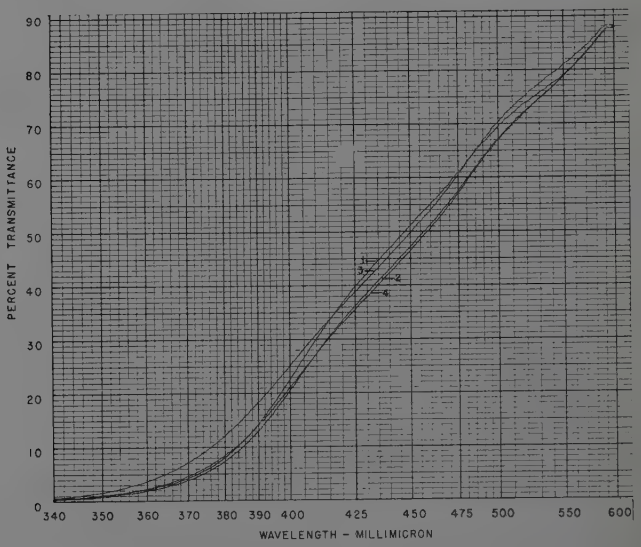

Figure 15. Transmittancy curves of solutions of glucose and glycine. (1) pH at 4.0, (2) pH at 6.5, (3) pH at 9.0, (4) pH at 7.3

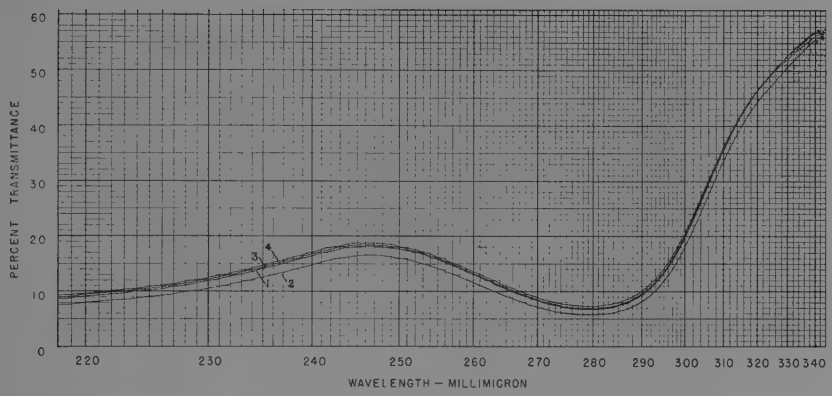

Figure 16. Transmittancy curves of colored solutions from the thermal degradation of reducing sugars. (1) pH at 4.2, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

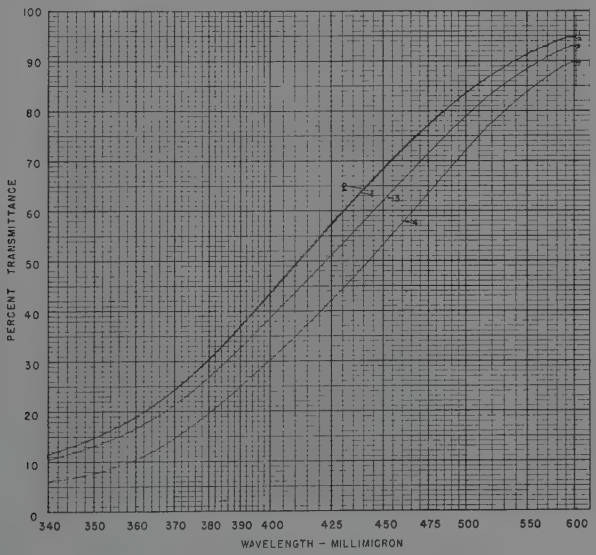

Figure 17. Transmittancy curves of colored solutions from the thermal degradation of reducing sugars. (1) pH at 4.2, (2) pH at 4.0, (3) pH at 6.5, (4) pH at 9.0

may be due to the keto-enol tautomerism of the carboxyl ion:

$$^{-}O-(\dot{C}=\dot{C})_n-\dot{C}=O \;=\; O=\dot{C}-(\dot{C}=\dot{C})_n-O^{-}$$

Spectrophotometric measurement indicated that at the inception of thermal degradation maximum transmittancy occurred at 240–250 mμ and minimum transmittancy at 270–290 mμ, as shown in Figures 2 and 16. This indicates the presence of a carbonyl group with one or more conjugated double bonds in the degradation products of reducing sugars.

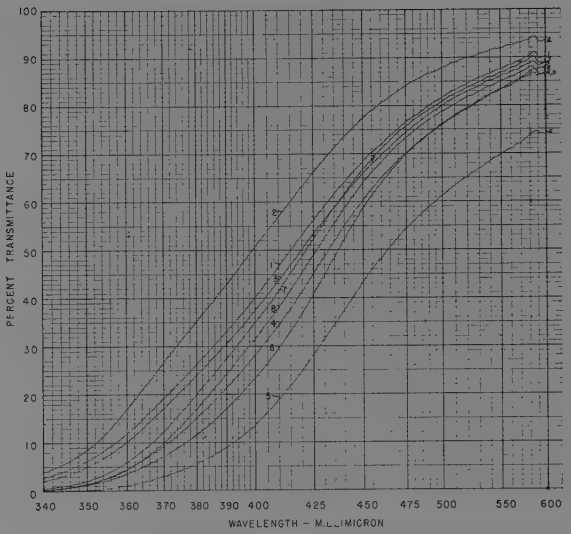

Figure 18. Transmittancy curves of raw sugar crystal solutions at pH 7.0. (1) Paauhau, (2) Honokaa, (3) Kohala, (4) Lihue-1, (5) Lihue-2, (6) Lihue-3, (7) Lihue-4, (8) Lihue-5

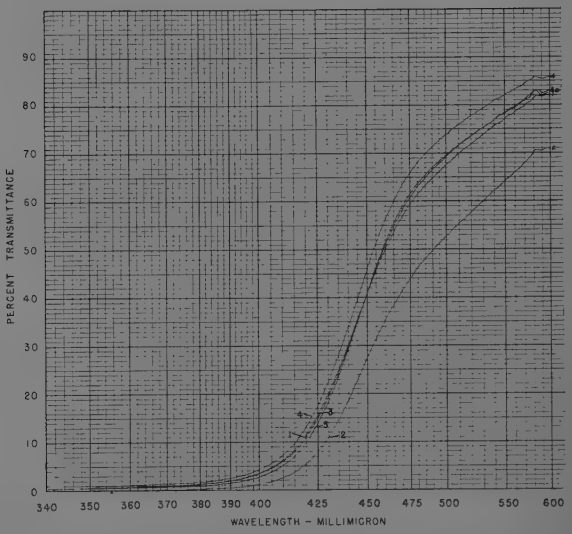

Figure 19. Transmittancy curves of raw sugar crystal solutions at pH 9.0. (1) Lihue-1, (2) Lihue-2, (3) Lihue-3, (4) Lihue-4, (5) Lihue-5

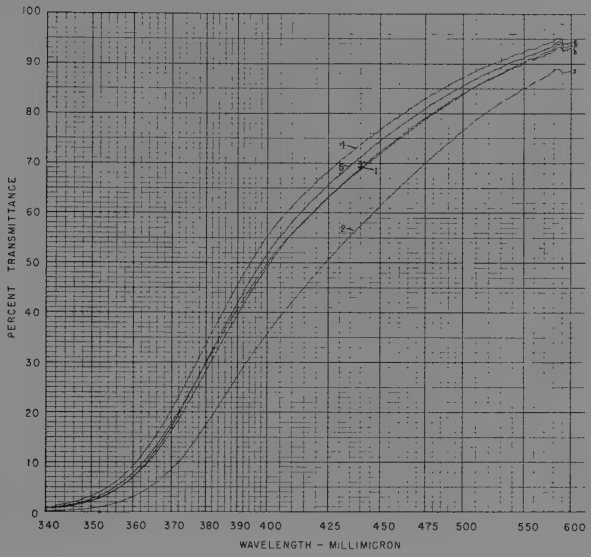

Figure 20. Transmittancy curves of raw sugar crystal solutions at pH 4.0. (1) Lihue-1, (2) Lihue-2, (3) Lihue-3, (4) Lihue-4, (5) Lihue-5

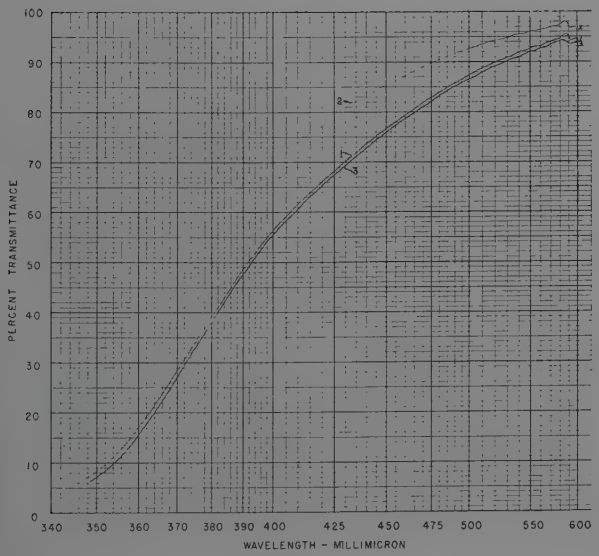

Figure 21. Transmittancy curves of raw sugar crystal solutions at pH 4.0. (1) Paauhau, (2) Honokaa, (3) Kohala

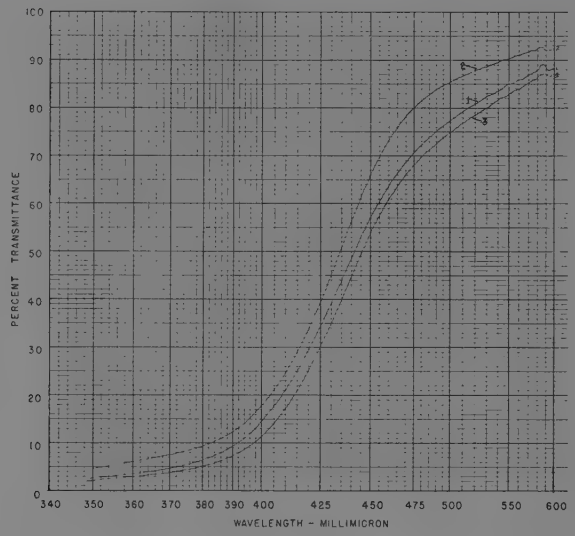

Figure 22. Transmittancy curves of raw sugar crystal solutions at pH 9.0. (1) Paauhau, (2) Honokaa, (3) Kohala

As thermal degradation proceeds, a shift of the peaks from the ultra-violet to the visible region takes place. The chromatograms of the sample solutions in which shifts have taken place revealed the presence of several acidic substances. This suggests oxidation during the degradation of sugars and during color formation.

When the solution containing the acidic substances became highly colored, precipitation occurred. This was attributed to polymerization or condensation during the latter stages of color formation. It then appears that degradation, oxidation, and polymerization are the principal reactions during the formation of color by thermal degradation of reducing sugars.

A comparison of the curves for raw sugar crystals and degraded sugar solutions at the visible range (Figures 11, 15, 17, 18, 19, 20, 21 and 22) showed that the coloring substances in the different raw sugars appear to be qualitatively the same as those of the thermal degradation products of reducing sugars. If it is assumed that the content of the polyphenolic compounds in raw sugar crystal is small, the pH sensitive color in raw sugar may be largely due to the thermal degradation products of reducing sugars. These products thus appear to be the principal contributors to the crystal color of raw sugar.

Spectrophotometric measurement of the synthetically prepared colored products in the ultraviolet region and paper chromatographic results indicated that the formation of the coloring substances from reducing sugars and melanoidin may have started from the same substance or substances arising from the thermal degradation of reducing sugars. It may be that the first step for the formation of color, with or without the presence of an amino acid, is the transformation of

the reducing sugar to a common color precursor. The amino acid may have also catalyzed the initial thermal degradation of the sugar. The rate of the transformation or the rate of the color formation is also dependent on the presence of certain organic and inorganic substances. The subsequent development of color and the formation of insoluble matter result from the interaction of the amino acid and the degradation products followed by polymerization.

As shown on the chromatograms, melanoidin is a mixture of several compounds. The color of melanoidin is not affected by pH changes to the same degree as the color of the substances from the thermal degradation of reducing sugars (Figures 14, 15 and 17). It may be that the carboxyl ion responsible for the keto-enol tautomerism is blocked in some manner. A comparison showed that the transmittancy curves at the visible region for raw sugar solutions probably result in large measure from the color substances from the thermal degradation of reducing sugars and, to a lesser degree, from melanoidin. The rate of formation of melanoidin and the color substances from the thermal degradation of reducing sugars are dependent upon pH, temperature, the kind and quantity of amino acids and reducing sugars, and catalyzing substances present.

Based upon the results obtained during the investigation, it is possible to differentiate between the color due to the substances from the thermal degradation of reducing sugars and that due to melanoidin. These two types of color are found to be responsible for a large proportion of crystal color of raw sugar. It has been reported that the decolorization of the products from the thermal degradation of reducing sugars is considerably easier than that of melanoidin (4). It should thus be possible to determine the relative quantities of each. A study of the reaction mechanisms for the formation of these two types of color present in raw sugar crystals is anticipated in future work.

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CYTOLOGICAL STUDIES IN *SACCHARUM* AND ALLIED GENERA

VI. Chromosome Numbers in *S. officinarum* and other Noble Sugar Canes

Sam Price[1]

INTRODUCTION

From time to time over the past few years, the writer has studied chromosome numbers in some of the noble sugar canes and has now accumulated chromosome counts for 69 clones (varieties). Several of these counts have already been published, and some only confirm the results of other authors. Included, however, are counts for 45 noble canes whose chromosome numbers have not previously been reported in the sugar cane literature.

In this article the writer's results are combined in a single list with the chromosome numbers of noble canes already published. It is hoped that this tabulation of data from widely scattered literature will provide a convenient reference for interested sugar cane researchers. The cytological evidence for prevalent generalizations about the noble canes can now be evaluated.

TERMINOLOGY

Dutch sugar cane breeders in Java coined the useful and descriptive term "noble" cane to designate the large-stemmed, soft-fleshed, tropical canes that were widely cultivated for chewing in Polynesia, Melanesia, Indonesia, the Philippine Islands, and southeast Asia, long before European explorers entered that part of the world. The term applies equally to the "original" canes (clones that have been and still can be collected in native gardens, as well as similar clones of unknown origin) and to new canes produced by interbreeding them.

Several clones have at one time or another been included among the noble canes although their morphological and cytological features set them apart from the others. Hybrid ancestries have been proposed for most of these clones, yet they remain more closely allied with the typical noble canes than with any other group of sugar canes. It is convenient, therefore, to speak of these varieties as the "atypical" noble canes.

The botanical name *Saccharum officinarum* L. was once used synonymously with the common term noble cane. Presently, however, its use is limited to the 80-chromosome clones. This use eliminates from *S. officinarum* the suspected hybrids just designated as the atypical noble canes. Neither the botanical name *S. officinarum* nor the common name noble cane can properly be applied to the cytologically complex sugar canes of known interspecific hybrid origin now cultivated by the sugar industry.

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MATERIALS AND METHODS

The writer studied clones from two sugar cane collections—the breeding collection of the Experiment Station of the Hawaiian Sugar Planters' Association (HSPA), and the World Collection maintained by the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture (USDA). Table 1 shows which of the two collections provided material for the writer's chromosome counts. Under "Source", importation ("Imp.") numbers indicate clones from the USDA collection, and "Hawaii" indicates clones from the HSPA collection. ("Imp." numbers are also given when other authors so identified their clones.) Some of the chromosome counts were obtained from iron-aceto-carmine squashes of pollen mother cells. Others were obtained from squashes of meristematic leaf tissue (31).

Usually only the first chromosome count published for each clone is given in Table 1. Subsequent reports are cited if there have been differences or if confirmation seems desirable. However, all of the writer's counts are included, even when they only confirm previously published observations.

Although some chromosome counts came from studying somatic cells and some from studying pollen mother cells, they are, for convenience, all given as $2n$ numbers in Table 1.

Frequently, in studies of sugar cane cytology, chromosome numbers can be closely approximated, but no cell can be found in which every chromosome is clearly seen and exactly interpreted. The qualified counts that result are written *ca.* 80, 79-81, or 79-**80**, for example. In the last count, the number in bold face is preferred.

The strikingly different chromosome numbers reported for several clones probably stem from mislabeling. The incorrect count is usually obvious. These counts, as well as others also thought to be erroneous, are enclosed in parentheses in Table 1.

TABLE 1. CHROMOSOME NUMBERS IN NOBLE SUGAR CANES.

Clone	Origin	Parentage	2n	Authority	Source
Unnamed clone	Unknown	Unknown	(*ca.* 68)	Kuwada (17)	Japan
A_2	India	"	80	Raghavan (39)	India
Ajax	Fiji	Badila × ?	80	Stevenson (47)	Barbados
Ancha	Taiwan	Unknown	80	Moriya (24)	Taiwan
Ardjoeno	Java	"	80	Bremer (4)	Java
247 B.	"	Unknown[1]	80	" "	"
			80	Price (32)	Hawaii
B. 391	Barbados	Ba. 11569 × ?	80	Stevenson (48)	Barbados
B. 417	"	B. 6835 × ?	80	" "	"
			78–**80**	Price (37)	Hawaii
B. 603	"	Ba. 6032 × ?	80	Stevenson (46)	Barbados
B. 2935	"	Ba. 11569 × Ba. 6032	80	" "	Barbados
B. 3013	"	Ba. 11569 × ?	80	" (48)	"
B. 3412	"	D. 74 × ?	80	Raghavan (39)	India
B. 6835	"	B. 1379 × ?	80	Price (37)	Hawaii
Ba. 2471	"	B. 3390 × ?	(148)	Li (20)	Taiwan
Ba. 6032	"	B. 7169 × ?	80	Stevenson (48)	Barbados
Ba. 11569	"	B. 16536 × ?	80	Stevenson (48)	Barbados
			78–**80**	Price (37)	Hawaii
Badila	New Guinea	Unknown	80	Moriya (23)	Taiwan
Badila Fiji	N.G. *via* Fiji	"	*ca.* 80	Price (37)	Hawaii
Bandjermasin Hitam	Borneo	"	80	Bremer (4)	Java

TABLE 1. continued

Clone	Origin	Parentage	2n	Authority	Source
Barbados White Sport	Barbados	"	80	Price (37)	Hawaii
Batjan	Java	"	80	Bremer (4)	Java
B. 50 F 1	Barbados	B. 2935 × self	80	Stevenson (46)	Barbados
B. 50 F 3	"	" "	80	" "	"
B. H. 10 (12)	"	B. 6835 × B. 4578	80	Bremer (9)	Java
			80	Price (37)	Hawaii
Big Ribbon	Unknown	Unknown	*ca.* 80	" "	"
Black Borneo	Borneo	"	80	Bremer (6)	Java
Black Cheribon	Java	"	80	" (4, 5)	"
Branchue Rayee	Unknown	"	88–90	" (9)	"
26 C 188	Hawaii	Yellow Caledonia × H. 109	*ca.* 80	Price (32)	Hawaii
27 C 346	"	Yellow Caledonia × H. 109	80	" (37)	"
27 C 556	"	Yellow Caledonia × D. 1135	80	" (32)	"
Cana Blanca	Unknown	Unknown	80	" (33)	Imp. 194
Cavangerie	New Caledonia[2]	"	80	Bremer (9)	Java
Cavengerie	" "	"	80	Price (37)	Hawaii
Chino	Hawaii	Unknown	*ca.* 80	Price (37)	Hawaii
Chittan	India	"	*ca.* 80	Dutt (12)	India
			80	Raghavan (43)	"
C.P. 36–116	Canal Point, Fla.	Louisiana Purple × ? or self	80	Stevenson (47)	Barbados
Crystalina	Unknown	Unknown	80	Brandes (2)	USDA
			80	Price (32)	Hawaii
D. 74	British Guiana	White Transparent × ?	80	Brandes (2)	USDA
			80	Parthasarathy (30)	India
D. 117	" "	White Transparent × ?	80	Price (37)	Hawaii
D. 1135	" "	D. 103 × ?	80–84	Bremer (7)	Java
			80	Price (32)	Hawaii
D.I. 46	Java	Black Cheribon × Batjan	(125)	Li (18)	Taiwan
D.I. 52	"	Black Cheribon × Batjan	*ca.* 80	Bremer (5)	Java
			80	Price (37)	Hawaii
E.K. 2	"	Bandjermasin Hitam × Fidji[3]	80	Bremer (5)	Java
			(120)	Li (18)	Taiwan
E.K. 28	"	Unknown[4]	80	Bremer (5, 7)	Java
			80	Rumke (45)	"
			80	Nishiyama (26)	Saipan
			80	Li (18)	Taiwan
			83	Stevenson[1](46,49)	Barbados
F. 122	Taiwan	Badila × E.K. 28	*ca.* 120	Li (18)	Taiwan
			ca. 130	Moriya (25)	"
			107–110	Price (37)	Hawaii
F.C. 306	Puerto Rico	D. 433 × ?	80	Bremer (9)	Java
Fidji	Fiji	Unknown	80	Bremer (4)	Java
Fiji 19	"	"	80	Price (37)	Imp.2063
Fiji 20	"	"	80	" "	Imp.2064
Fiji 21	"	"	79–80	" "	Imp.2065
Fiji 24	"	"	80	" "	Imp.2067
G. 119	Guadeloupe	Ba. 11569 × ?	79–80	Bremer (9)	Java
Green German New Guinea	New Guinea	Unknown	*ca.* 80	" (4)	"
Green Sport	India	Sport of Striped Mauritius	80	Raghavan (40)	India
H. 20	Hawaii	D. 1135 × ?	80	Li (20)	Taiwan
H. 109	"	Lahaina × ?	80	Weller (50)	Hawaii
			80	Price (32)	"
H. 456	"	H. 240 × ?	80	" "	"
H. 8965	Hawaii	H. 109 × ?	76–80	Price (37)	Hawaii
H. 9811	"	Possibly Badila × ?	80	" (32)	"
H. 27–8101	"	25 C 14 × Badila	80	" "	"
H. 33–7535	"	H. 27–100 × ? or self	80	" "	"

TABLE 1. continued

Clone	Origin	Parentage	2n	Authority	Source
H. 34–861	"	H. 27–100 × ? or self	80	" "	"
Ie Ie	New Caledonia[2]	Unknown	*ca.* 80	" (37)	"
Iliopua	Hawaii	"	80	" "	"
Kajla	India	"	68	Parthasarathy (29)	India
Kandy	Ceylon	"	80	Bremer (9)	Java
Kaludai Boothan	India	Possible Sport from Chittan	80	Parthasarathy (30)	India
Kara Kara Wa	Fiji[5]	Unknown	**127**–128	Bremer (7)	Java
Kea or Kokea	Hawaii	"	80	Price (37)	Hawaii
Keong	Unknown	"	79–80	Bremer (9)	Java
Koesoemo	Java	Djamprok × Loethers	92–93	Bremer (5)	"
Korpi	New Guinea	Unknown	80	Price (37)	Hawaii
Koshu Fleshy Cane	South China	"	80	Moriya (24)	Taiwan
Lahaina	Unknown	"	80	Bremer (5)	Java
			80	Price (32)	Hawaii
Lahi (Haw'n. Orig. 7)	Hawaii	Unknown	*ca.* 80	Price (37)	Hawaii
Lahi (Haw'n. Orig. 10)	"	"	80	" "	"
Lakhapur	India	"	80	Parthasarathy (30)	India
Laukono	Hawaii	"	80	Price (37)	Hawaii
Lehu	Hawaii?[6]	"	80	Bremer (9)	Java
Loethers	Unknown	"	99	Bremer (5, 10)	"
			(90)	Nishiyama (28)	Hawaii
			99	Price (37)	Imp. 723
			99	Price (37)	Imp.3065
Louisiana Purple	"	"	80	Brandes (3)	USDA
			80	Price (37)	Hawaii
Luzon White	Philippines	"	80	Moriya (24)	Taiwan
Manjri Red	India	"	80	Raghavan (42)	India
Manoa 160	Hawaii	Striped Tip × ?	*ca.* 80	Price (37)	Hawaii
Manoa 213	"	Badila × ?	*ca.* 80	" "	"
Manoa 301	"	Striped Tip × ?	80–87	" "	"
Mauritius 55 Striped	India	Sport of Mauritius 55	80	Anonymous (1)	India
Mia-Co-Ke	Thailand	Unknown	80	Moriya (24)	Taiwan
Mia-Go-Cat	"	"	80	" "	"
Moano	Hawaii	Unknown	79–81	Bremer (9)	Java
27 M.Q. 1124	Australia	Korpi × self	80	Price (37)	Hawaii
M. 1900 S.	Mauritius	Unknown	*ca.* 80	Price (37)	"
Muk Che	Singapore ? *via* China	"	80	" "	"
Naz Reunion	Unknown	"	109–110	Bremer (6)	Java
N.C. 25	New Caledonia	"	80	Brandes (3)	Imp. 888
N.C. 32	" "	"	80	" "	Imp. 892
28 N.G. 6	New Guinea	"	80	Price (37)	Imp. 630
28 N.G. 13	" "	"	80	Stevenson (48)	Barbados
			ca. 80	Price (37)	Imp. 632
28 N.G. 87	" "	"	80	" "	Hawaii
28 N.G. 106	" "	"	(98)	Brandes (3)	Imp. 508
			80	Price (37)	Imp. 508
28 N.G. 217	" "	"	80	" "	Imp. 662
28 N.G. 269	" "	"	80	" "	Hawaii
51 N.G. 89	" "	"	80	" "	Imp.1971
51 N.G. 95	" "	"	80	" "	Imp.1978
51 N.G. 103	" "	"	80	" "	Imp.1984
51 N.G. 121	" "	"	80	" "	Imp.1990
51 N.G. 131	" "	"	80	" "	Imp.1999
51 N.G. 146	" "	"	80	" "	Imp.2011
N.H. 2	New Hebrides	"	(98–100)	Brandes (3)	Imp. 922
Opukea	Hawaii	"	80	Bremer (9)	Java
Oramboo	New Guinea	"	80	Price (37)	Hawaii
Otaheite	Unknown	"	80	Brandes (2)	USDA
			80	Stevenson (46)	Barbados

TABLE 1. concluded

Clone	Origin	Parentage	2n	Authority	Source
P.889/2 ("Triploid")	India	Chittan × self	120	Raghavan (41)	India
Padangsche	Sumatra	Unknown	80	Price (37)	Hawaii
Pakaweli	Hawaii	"	80	" "	Imp. 824
Pegu 3	Burma	"	79–80	Bremer (9)	Java
Pegu 5	"	"	80	" "	"
Pohina	Hawaii	"	80	" "	"
			80	Price (37)	Hawaii
P.O.J. 100	Java	Bandjermasin Hitam × ?[7]	89	Bremer (5)	Java
			88	Nishiyama (28)	Hawaii
P.O.J. 100 × self	Saipan	P.O.J. 100 × ? or self	178	" (27)	Saipan
Poovan	India	Unknown	*ca.* 80	Dutt (12)	India
Punahou 78	Hawaii	26 C 148 × 20 S 15	80	Price (37)	Hawaii
Puri	India	Unknown	80	Dutt (12)	India
Purple Mauritius	Unknown	"	80	Raghavan (38)	"
Q. 13	Australia	Possibly Korpi × H.Q. 409	80	Buzacott (11)	Australia
Q. 44	"	Unknown	80	" "	"
Q. 116	Australia ?	"	80	Li (20)	Taiwan
R.G. 667	Java	"	80-84	Bremer (7)	Java
Red Egyptian	Unknown	"	(28)	Franck (13)	"
			ca. 80	Bremer (4)	"
Rose Bamboo	"	"	80	Li (19)	Taiwan
			ca. 80	Price (32)	Hawaii
S.C. 12 (4)	Barbados *via* Virgin Is.	B. 6835 × B. 4578	80	Bremer (9)	Java
Selemi Bali	Unknown	Unknown	*ca.* 80	Price (37)	Hawaii
Shamshara	India	"	80	Dutt (12)	India
Simpson	Florida	"	80	Brandes (2)	USDA
Striped Cheribon	Unknown	"	80	Rasool Batcha (44)	India
Striped Mauritius	"	"	80	Raghavan (38)	India
Striped Mexican	"	"	80	Price (35)	Hawaii
Striped Tip	"	"	88	Bremer (9)	Java
S.W. 3	Java	Black Cheribon × Batjan	80	Bremer (5)	Java
			(120)	Li (18)	Taiwan
S.W. 111	Java	Black Cheribon × Batjan	80	Bremer (5)	Java
Tanangge Bola	Celebes	Unknown	80	" (9)	"
Teboe Sampang A.	Java	"	80	" (4)	"
Tolo Fau Lau I.	Samoa	"	*ca.* 80	Price (37)	Imp.1803
Uahi-a-Pele	Hawaii	"	80	" "	Hawaii
Vellai	India	"	80	Dutt (12)	India
Yellow Caledonia	Unknown	"	78–80	Price (37)	Hawaii
Yellow Egyptian	"	"	81	Bremer (8)	Java

[1] The parentage Black Cheribon × Fidji, often given for 247 B., is no more than a guess (15).

[2] Horne (14) listed both Kavengeri (synonymous with Cavangerie, Cavengerie, Ie Ie, Otamite, etc.) and Onatamite (probably the same as Otamite) as canes native in New Caledonia that were introduced in Mauritius between 1855 and 1877.

[3] The parentage Bandjermasin Hitam × Fidji is from Jeswiet (16). Bremer (5) proposed that Lahaina was the female parent.

[4] The parentage P.O.J. 100 × E.K. 2, often given for E.K. 28, is no more than a guess (5).

[5] Horne (14) listed Kara-Ka-Rawa (obviously only a spelling variation) among canes he collected in Fiji and sent to Mauritius, 1877–1879.

[6] Lehu may have reached Hawaii after Captain Cook's discovery of those islands.

[7] An open-pollinated panicle of Bandjermasin Hitam produced P.O.J. 100. The morphology of P.O.J. 100 led Jeswiet (15) to suppose that Loethers was its father.

SYNONOMY

The task of preparing a list of noble sugar canes is fraught with difficulties arising from synonomy. For example, Cana Blanca, Otaheite, and Lahaina are said to be identical. Furthermore, Shamshara is supposed to be the same as Otaheite, and Lahaina the same as Vellai. Dutt and Subba Rao (12) said, however, that Shamshara and Vellai differ.

The noble cane Cavangerie studied by Bremer (9) was imported in Java from Hawaii, and, therefore, is probably identical with Cavengerie of the Hawaiian collection. If so, it is not the same as Yellow Bamboo, as Bremer suggested. Other synonyms are Otamite, Port Mackay, Bullock Heart, Kavangri, and Kavengeri. (This noble cane is not to be confused with Kavangire, which is a clone of *S. sinense* Roxb., Pansahi group.) Although Cavengerie is not native in Hawaii, it has been collected from Hawaiian gardens under the name Ie Ie (A. J. Mangelsdorf, personal communication).

The once important commercial cane H. 109, bred in Hawaii, has also found its way into native gardens. It was collected in Samoa as Tolo Limu (A. J. Mangelsdorf, personal communication).

Another sort of difficulty with synonomy is illustrated by Puri, said to be the same as Creole. Creole is a synonym for Yellow Egyptian. Yet, the chromosome number reported for Puri is $2n = 80$ and for Yellow Egyptian, $2n = 81$. According to a personal communication from Carl O. Grassl, Creole (now lost from the USDA collection) differed distinctly from Puri, but Creoula (still in the collection) and Puri are the same.

Since contradictions in synonomy are not easily resolved, the names of clones are listed in Table 1 as they were given by the authors cited, except that Dutch adjectives, such as geel (yellow), gestreept (striped), and zwart (black), are translated into English. This practice follows a precedent set by the Dutch authors themselves when they published in the English language. Synonyms that may be helpful in using Table 1 are compiled in Table 2. Most of these synonyms have been gathered from the literature. A few come from the personal communications of colleagues.

TABLE 2. SYNONYMS

Ardjoeno = Redjoeno, Teboe Ardjoeno.
Badila = N.G. 15, N.G. 188, 14 N.G. 188, 96 N.G. 15.
Big Ribbon = Caledonia Ribbon, Striped Tanna.
Black Borneo = Zwart Borneo.
Black Cheribon = Louisiana Purple, Purple Mauritius, Red Egyptian, Rood Egyptisch, Zwart Cheribon.
Blanche Reunion = Branchue Rayee, Soerat Mauritius, Striped Tip.
Bourbon = Cana Blanca, Lahaina, Otaheite, Shamshara, Vellai.
Branchue Rayee = Blanche Reunion, Soerat Mauritius, Striped Tip.
Bullock Heart = Cavangerie, Cavengerie, Ie Ie, Kavangri, Kavengeri, Otamite, Port Mackay.
Caledonia Ribbon = Big Ribbon, Striped Tanna.
Cana Blanca = Bourbon, Lahaina, Otaheite, Shamshara, Vellai.
Cavangerie = Bullock Heart, Cavengerie, Ie Ie, Kavangri, Kavengeri, Otamite, Port Mackay.
Cavengerie (See Cavangerie).
Creole = Geel Egyptisch, Yellow Egyptian.
Creoula = Puri.
Crystalina = Rose Bamboo, White Preanger, White Transparent.
Elephant Cane of India = Pegu 3.
Geel (See Yellow).
Gestreept (See Striped).
Green German New Guinea = Groen Duitsch Nieuw Guinea.
Groen (See Green).
H. 109 = Tolo Limu.
Hawaiian Original 1 = Ohia.

TABLE 2. concluded

Hawaiian Original 2 = Pakaweli.
Hawaiian Original 6 = Waiohia.
Hawaiian Original 7 = Lahi.
Hawaiian Original 10 = Lahi.
Hawaiian Original 15 = Laukona.
Hawaiian Original 24 = Akoki.
Hawaiian Original 29, 30 = Iliopua.
Hawaiian Original 31 = Kea, Kokea.
Hawaiian Original 32 = Halalii.
Hawaiian Original 34 = Opukea.
Hawaiian Original 43 = Uhu.
Hawaiian Original 48 = Moano.
Hawaiian Original 50 = Uahi-a-Pele.
Hawaiian Original 51 = Pohina.
Hawaiian Original 52 = Uala (Kauai).
Hawaiian Original 61 = Uala.
Hawaiian Original 75 = Lehu.
Halalii = Hawaiian Original 32.
Hottai = Keli, Poovan, Pundia.
Ie Ie = Bullock Heart, Cavangerie, Cavengerie, Kavangri, Kavengeri, Otamite, Port Mackay.
Iliopua = Hawaiian Original 29, 30.
Kavangri = Bullock Heart, Cavangerie, Cavengerie, Ie Ie, Kavengeri, Otamite, Port Mackay.
Kavengeri (See Kavangri).
Kea = Hawaiian Original 31, Kokea.
Keli = Hottai, Poovan, Pundia.
Keong = Pegu 5.
Kokea = Hawaiian Original 31, Kea.
Korpi = N.G. 124, 14 N.G. 124.
Lahaina = Bourbon, Cana Blanca, Otaheite, Shamshara, Vellai.
Lahi = Hawaiian Original 7 and 10.
Laukona = Hawaiian Original 15.
Lehu = Hawaiian Original 75.
Louisiana Purple = Black Cheribon, Purple Mauritius, Red Egyptian, Rood Egyptisch, Zwart Cheribon.
Luzon White = White Manila, Wit Manila.
Moano = Hawaiian Original 48.
N.G. 15 = Badila, N.G. 188, 14 N.G. 188, 96 N.G. 15.
N.G. 124 = Korpi, 14 N.G. 124.
N.G. 188 = Badila, N.G. 15, 14 N.G. 188, 96 N.G. 15.
N.G. 190 = 14 N.G. 190, Oramboo.
96 N.G. 15 = Badila, N.G. 15, N.G. 188, 14 N.G. 188.
14 N.G. 124 = Korpi, N.G. 124.
14 N.G. 188 = Badila, N.G. 15, N.G. 188, 96 N.G. 15.
14 N.G. 190 = N.G. 190, Oramboo.
Oramboo = N.G. 190, 14 N.G. 190.
Otaheite = Bourbon, Cana Blanca, Lahaina, Shamshara, Vellai.
Otamite = Bullock Heart, Cavangerie, Cavengerie, Ie Ie, Kavangri, Kavengeri, Port Mackay.
Opukea = Hawaiian Original 34
Pegu 3 = Elephant Cane of India.
Pegu 5 = Keong.
Pohina = Hawaiian Original 51
Poovan = Hottai, Keli, Pundia.
Port Mackay = Bullock Heart, Cavangerie, Cavengerie, Ie Ie, Kavangri, Kavengeri, Otamite.
Pundia = Hottai, Keli, Poovan.
Puri = Creoula.
Purple Mauritius = Black Cheribon, Louisiana Purple, Red Egyptian, Rood Egyptisch, Zwart Cheribon.
Red Egyptian (See Purple Mauritius).
Redjoeno = Ardjoeno, Teboe Ardjoeno.
Rood (See Red).
Rose Bamboo = Crystalina, White Preanger, White Transparent.
Sampang A = Teboe Sampang A.
Shamshara = Bourbon, Cana Blanca, Lahaina, Otaheite, Vellai.
Soerat Mauritius = Blanche Reunion, Branchue Rayee, Striped Tip.
Striped Cheribon = Striped Mexican, Striped Preanger.
Striped Mexican (See Striped Cheribon).
Striped Preanger (See Striped Cheribon).
Striped Tanna = Big Ribbon, Caledonia Ribbon.
Striped Tip = Blanche Reunion, Branchue Rayee, Soerat Mauritius.
Tanna Blanca = Yellow Caledonia.
Teboe Ardjoeno = Ardjoeno, Redjoeno.
Teboe Sampang A = Sampang A.
Tolo Limu = H. 109.
Uahi-a-Pele = Hawaiian Original 50.
Uala = Hawaiian Original 61.
Uhu = Hawaiian Original 43.
Vellai = Bourbon, Cana Blanca, Lahaina, Otaheite, Shamshara.
Waiohia = Hawaiian Original 6.
White Manila = Luzon White, Wit Manila.
White Preanger = Crystalina, Rose Bamboo, White Transparent.
White Transparent = (See White Preanger).
Wit (See White).
Yellow Caledonia = Tanna Blanca.
Yellow Egyptian = Creole, Geel Egyptisch.
Zwart (See Black).

COMMENTS ON PARTICULAR CLONES

F. 122. The recorded parentage of F. 122 is Badila × E. K. 28, and Moriya (25) indicated that this parentage is reliable. Speaking of F. 122, Moriya said, ". . . judging from its stem shape and color, that resemble Badila very much, it must surely have received many Badila chromosomes". However, a note in the HSPA records about F. 122 imported in Hawaii from Taiwan suggests that the recorded parentage is wrong: "This cane shows no evidence of Badila blood." These apparent contradictions, together with the different chromosome numbers recorded (Table 1), suggest that clones labeled F. 122 in different collections may not be identical.

S. W. 111. S. W. 111 is an 80-chromosome noble cane bred in Java. However, the HSPA collection once contained a different clone which also bore the label S. W. 111. After the latter was found to have $2n = ca.$ 106-112, an inspection of the clone showed that it was neither the true S. W. 111 nor any other noble cane. This mistake was discovered even as seed was germinating from a cross in which the mislabeled clone was pollinated by Mol. 1032, a 64-chromosome clone of *S. spontaneum* L. The cross gave rise to several seedlings (H. 53-9081 through H. 53-9126), two of which were studied by Nishiyama (28). Although Nishiyama stated that the female parent "probably" was not the true S. W. 111, the certainty that it was not is reemphasized here so that no false interpretation can ever be drawn from Nishiyama's observations.

Loethers. Nishiyama (28) studied the meiotic chromosome configurations at diakinesis and first metaphase in pollen mother cells of Loethers, an atypical noble cane. Because of difficulties which he acknowledged in distinguishing between certain bivalents and trivalents, his chromosome counts varied from 89 to 91, but he concluded that $2n = 90$ was probably correct.

Bremer (10), who had already reported $2n = 98$-99 and $2n = 99$-103 in Loethers (5, 7), returned to his original slide and reaffirmed his count $2n = 99$. Bremer suggested that Nishiyama had worked with a clone mislabeled Loethers just as he had worked with a clone mislabeled S. W. 111.

The writer examined leaf squash preparations of Loethers, Imp. 723 of the USDA World Collection (a 1932 importation from Java), and found that indeed it has $2n = 99$. Then cuttings from the HSPA collection (Nishiyama's source) were imported (Imp. 3065), and Loethers from HSPA was found to contain $2n = 99$ also. Loethers in the Hawaiian collection, therefore, is not mislabeled.

The different chromosome numbers reported for Loethers attest to the difficulties intrinsic in the material. They also point to the risks involved in interpreting meiotic configurations in the sugar canes. These risks are multiplied in complex clones which exhibit unpaired chromosomes and possibly even multivalent configurations.

Hawaiian Originals. The native chewing canes of Hawaiian gardens are often called "Hawaiian Originals" to distinguish them from canes imported after Captain Cook's discovery of the islands and from the many canes produced by Hawaii's sugar cane breeders. Chromosome numbers of the Hawaiian Originals listed in Table 1 agree with the expected number ($2n = 80$) for *S. officinarum*. All these counts were taken from fertile clones.

Many Hawaiian Originals are infertile. In dissecting florets that had been fixed for pollen-mother-cell studies, the writer found that anthers were missing from the florets of infertile Hawaiian Originals. A tiny structure resembling a rudimentary floral axis grew from the apex of the ovaries in some clones. In other clones, both anthers and ovaries were replaced by such a structure. This sort of abortion was found in Akoki (Hawaiian Original 24), Halalii (Hawaiian Original 32), Ohia (Hawaiian Original 1), Uala (Hawaiian Original 61), Uala from Kauai (Hawaiian Original 52), Uhu (Hawaiian Original 43), Waiohia (Hawaiian Original 6), and the unnamed Hawaiian Original 71. Somatic studies are needed to determine whether these varieties with aborted florets conform to the expected chromosome number of noble sugar canes.

Incidentally, in Yellow Caledonia some of the florets are similarly aborted, some are normal, and others are transitional.

CHROMOSOME NUMBERS IN THE ORIGINAL NOBLE CANES

According to Brandes and Sartoris (2) there were, among the New Guinea canes collected in 1928, only 13.16 per cent that had 80 chromosomes, while 70.39 per cent had about 100, and 16.45 per cent had 110 to 149 chromosomes. No specific clones were mentioned, but probably among them were several clones of the so-called *S. edule* Hassk. and perhaps even some *S. officinarum* × *S. robustum* Brandes and Jeswiet hybrid derivatives. Nevertheless, since the majority of the 1928 New Guinea collection consists of noble canes, the notion grew that extended studies would show many of the original noble canes deviating radically from $2n=80$.

The notion is not supported by the chromosome numbers tabulated here. Table 1 contains 144 clones. (This total ignores synonomy and excludes erroneous counts.) Ninety-one of them are original noble canes of which 84 have 80, or probably 80, chromosomes. Only seven atypical clones—Branchue Rayee, Kajla, Kara Kara Wa, Loethers, Naz Reunion, Striped Tip, and Yellow Egyptian—have chromosome numbers that surely deviate from 80.

Li and his coworkers are presently studying the 1928 noble sugar cane collection. In a preliminary statement (21) they mentioned no specific clones but said that the chromosome numbers ranged from 64 to 128. However, the majority of the clones had 80 chromosomes.

CHROMOSOME NUMBERS IN PURPOSELY BRED NOBLE CANES

Of the 144 clones listed in Table 1, 53 were produced intentionally, either by collecting and germinating seed from open-pollinated panicles, or by purposely selfing or crossing noble canes. Five of the 53—F. 122, Koesoemo, Manoa 160, Manoa 301, and an unnamed seedling from P.O.J. 100 × self—were bred from atypical noble canes and must themselves be considered atypical. Descent from atypical noble canes has been suggested for two others—E.K. 28 and P.O.J. 100.

One of the intentionally produced plants, P. 889/2, has 120 chromosomes. If this plant is truly a "triploid" from Chittan × self, as it is said to be (41), and not a contaminant, it is the only "triploid" noble cane known. Because *S. officinarum* habitually transmits its somatic chromosome number maternally in certain other crosses (32), the origin of a 120-chromosome noble cane would logically be attributed to fertilization of an 80-chromosome egg cell by a normal 40-chromosome sperm nucleus ($2n + n$). Oddly enough, however, P. 889/2 was said to have developed parthenogenetically from a "triploid" egg (41).

All the remaining 45 noble canes that were intentionally produced have 80, or probably 80, chromosomes. The parents of these 45 clones can reasonably be *assumed* to have had 80 chromosomes also. But how much is actually *known* about the cytology of the parental clones?

The cytology of neither parent is known for 13 of the 45 clones. One parent of 21 other clones is known to have 80 chromosomes; the other parent is unknown cytologically. Finally, only 11 purposely bred noble canes have parental clones that are both known to have 80 chromosomes.

CHROMOSOME TRANSMISSION

Because *S. officinarum* so consistently transmits unexpected chromosome numbers in certain crosses (32), it may be surprising that so many noble canes have just 80 chromosomes. The preponderance of 80-chromosome clones among both original and purposely bred noble canes naturally leads to the conclusion that *S. officinarum* is just as consistently normal in transmitting its expected gametic number in intraspecific crosses as it is consistently peculiar in transmitting its somatic number in certain interspecific crosses. The preceding paragraph shows, however, that critical experimental data bearing upon this conclusion are meager.

A preliminary account has already been given (34) of studies intended to provide more extensive and unbiased data from unselected noble cane progenies. These studies of unselected progenies support rather than modify the conclusion that *S. officinarum* transmits normal gametic chromosome numbers in intraspecific crosses. A detailed account of this work is to be presented elsewhere (36).

SUMMARY

A great majority (129 of 144) of the noble sugar canes have 80, or probably 80, chromosomes.

Normal cytological behaviour in *S. officinarum* × *S. officinarum* crosses is indicated although, in previous literature, critical data on this point are few.

Fertile Hawaiian Originals have 80, or probably 80, chromosomes. Chromosome numbers of the infertile Hawaiian Originals are not yet known.

The matter of a clone mistakenly labeled S. W. 111 is explained.

The chromosome number $2n = 99$ in Loethers is confirmed.

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